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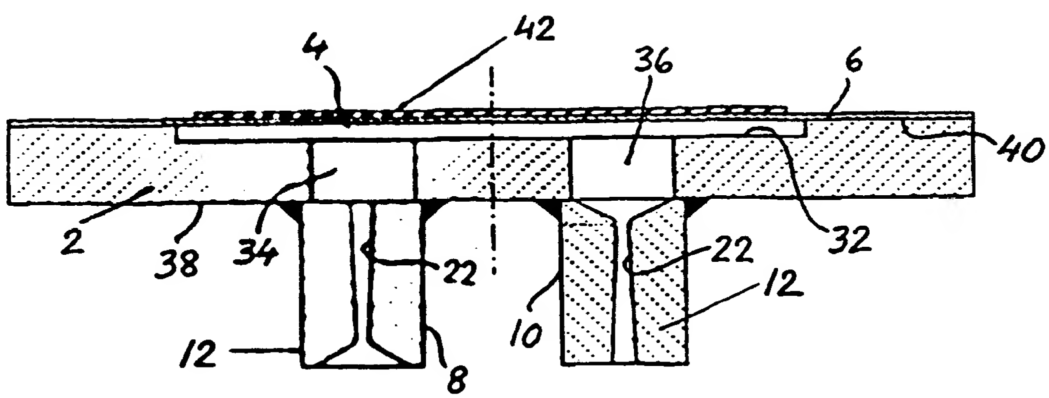
(54) Title: DISPLACEMENT PUMP OF DIAPHRAGM TYPE



(57) Abstract

A displacement pump with a pump housing (2) containing a pump chamber (4) of varying volume, the limiting walls of which comprising a moveable portion or diaphragm (6), the movement and/or deformation of which varies the pump chamber volume. The pump chamber has a fluid inlet (8) on the suction side of the pump and a fluid outlet (10) on the pressure side. Both the fluid inlet (8) and the fluid outlet (10), or possibly only one of them, comprises a constricting element (12) which, for the same flow, has a larger pressure drop in one flow direction (the nozzle direction) than in the opposite flow direction (the diffusor direction). A drive means (42) is coupled to the diaphragm (6), whereby the diaphragm can be caused to oscillate, so that the fluid volume in the pump chamber (4) is caused to pulsate and thereby produce a net flow of fluid through the pump.

Displacement pump of diaphragm type

The present invention relates to a displacement pump of the type described in the preamble to the attached claim 1.

State of the art

Displacement pumps of this general type are usually called diaphragm pumps. Such a pump has a pump housing which contains a pump chamber (pump cavity) of variable volume. The pump chamber is defined by walls including at least one elastically deformable wall portion, for example in the form of a flexible diaphragm, which by means of a suitable type of actuator can be imparted an oscillating movement. On the suction side of the pump, there is a fluid inlet to the pump chamber, and, on its pressure side, a fluid outlet from the pump chamber. The fluid flow through the inlet and outlet is controlled by check valves. These check valves can be of many different types. For example, a check valve can be used where the flow preventing element is a ball or a hinged flap. The check valves are so arranged in the fluid inlet and fluid outlet that the check valve at the inlet is open and the check valve at the outlet is closed during the intake phase (when the volume of the pump chamber is increasing), while the inlet check valve is closed and the outlet check valve is open during the pumping phase (when the volume of the pump chamber is decreasing). The movement and change in shape of the flexible diaphragm causes the volume of the pump chamber to vary, and thus creates the displacement effect, which, thanks to the check valves, is translated into a net flow from the fluid inlet to the fluid outlet, and thus a pulsating flow at the pressure side of the pump (the outlet side).

Pumps with check valves passively controlled by the flow direction and pressure of the pump fluid have, however, certain characteristics which can be disadvantageous especially in certain applications or fields of use for such pumps.

One example of such disadvantages is the excessively great drop in pressure over the check valves and the risk of wear and fatigue damage to the moving, flow preventing elements of the valves, which can result in reduced life and reduced reliability of the pump. For pumping, especially sensitive fluids, primarily liquids, there is also the risk that the moving valve elements can damage the fluid or negatively affect its properties.

Purpose of the invention

For the above applications and special fields of use, there is a pronounced need for pumps which completely lack moving parts, such as check valves, or only have extremely few such moving parts.

The primary purpose of the present invention is therefore to provide a displacement pump of the type described by way of introduction which can be made completely without valves in the fluid inlet and/or fluid outlet.

The pump is to be a fluid pump which can be used and optimized for pumping both liquids and gases. It must also be able to be used for pumping fluids containing fluid born particles, e.g. liquids containing solid particles.

Description of the invention

The above mentioned purposes are achieved according to the invention by virtue of the fact that at least one of the fluid inlet and the fluid outlet comprises a constricting element which, for the same flow, has a greater

pressure drop over the element in one flow direction, the nozzle direction, than in its opposite other flow direction, the diffusor direction.

Particularly characteristic for the new type of displacement pump is that constricting elements with "fixed" geometry are used instead of the check valve(s) used in previously known types of diaphragm pumps, for example.

Further developments and preferred embodiments of the displacement pump according to claim 1 can also show the features disclosed in the independent claims 2-9.

For the pump according to the invention, in general the wall portion, which through its movement and/or change in shape causes the volume of the pump chamber to vary, can suitably be elastic in itself (i.e. cause its own spring action), but it is also quite possible to instead use a plastically deformable wall portion with a spring or a spring device coupled thereto, which returns the wall portion to its original position. The wall portion could even be the end surface of a reciprocating rigid piston. A pump according to the invention can be made of metal, polymer material, silicon or another suitable material.

In practice, it is suitable that both the fluid inlet and the fluid outlet be made of individual constricting elements of the type described. Both the constricting element of the fluid inlet and the constricting element of the fluid outlet are preferably arranged so that their diffusor direction agrees with the flow direction for the pulse volume flow from the fluid inlet to the fluid outlet.

In general, it can be said that the displacement pump of the invention is given its flow directing effect by virtue of the fact that the selected type of constricting

element has lower pressure losses when the element functions as a diffusor than when it functions as a nozzle. In this connection, it can be pointed out that the term diffusor refers to a flow affecting element or means which converts kinetic energy of a flowing fluid into pressure energy in the fluid. A nozzle is, in turn, an element or means which, while utilizing a pressure difference (over the nozzle), converts pressure energy in the flowing fluid into kinetic energy.

During the intake phase of the displacement pump (when the pump chamber volume increases), the inventive constricting element on the intake side of the pump functions as a diffusor with lower flow resistance than the inventive constricting element, functioning at the same time as a nozzle on the outlet side of the pump.

It follows therefrom that a larger fluid volume is sucked into the pump chamber via the inlet diffusor than via the outlet nozzle during the same suction phase. During the subsequent displacement phase ("pumping phase") of the pump, the constricting element on the inlet side will instead function as a nozzle with higher flow resistance than the constricting element on the outlet side of the pump functioning at the same time as the diffusor. This means that a larger volume of fluid is forced out of the pump chamber via the outlet diffusor than via the inlet nozzle during the last mentioned displacement or pumping phase. The result during a complete period (work cycle for the pump) will thus be that a net volume has been moved through the pump, i.e. pumped, from the inlet side to the outlet side, despite the fact that both constricting elements permit per se a fluid flow in both possible flow directions.

The constriction elements at the inlet and outlet of the pump chamber should preferably be directed so that the

diffusor directions of the elements agree with the flow direction for the pulsed flow from the fluid inlet and the fluid outlet. The elastically deformable wall portion of the pump chamber consists suitably of one or more flexible membranes, the movement and changing shape of which are achieved by suitable drive means which impart an oscillating movement to the membrane(s) which causes the fluid volume enclosed in the pump chamber to pulsate. Such a drive means can, for example, be a part of a piezo-electric, electro-static, electro-magnetic or electro-dynamic drive unit. It is also possible to use thermally excited membranes.

The pump housing itself with associated constricting elements can be made so that they constitute integral parts of an integral piece. The displacement pump according to the invention can also be made by a micro working process; the pump structure can, for example, be made of silicon.

A pump according to the invention can suitably be made with the aid of micro working methods, especially if the pump is made flat with the constricting elements and the cavity is lying in the same plane. The constricting elements should then be planar, i.e. have a rectangular cross-section.

Micro working methods refer essentially to those techniques which are used in the manufacture of micro electronics components. This manufacturing concept involves the mass production, from a base substrate (usually monocrystalline silicon), by planar, litographically defined, thin film technology, small identical components with advanced functions. The term micro working also encompasses various special processes, such as, for example, anisotropic silicon etching of monocrystalline silicon.

Examples of suitable inexpensive mass production methods include various types of processes for casting constricting elements and cavities. Possible suitable materials are different types of polymer materials, such as plastics and elastics.

The displacement pump according to the invention can, as can conventional membrane pumps, be provided with pressure equalizing buffer chambers, both at the pressure side of the pump and at its suction side. With such buffer chambers, the pressure pulses of the pulsed flow can be reduced to a significant extent.

The purposes stated above can be effectively achieved with a displacement pump according to the invention primarily by virtue of the fact that the new pump structure does not need to have any moving parts, and therefore the pump can be made simple and sturdy and thus guarantee high reliability. The pump according to the invention can be optimized for pumping either gas or liquid, and contain fluid born particles without impairing the function or reliability of the pump.

A displacement pump according to the invention can without a doubt be used within a number of fields. For example, the pump can be used as a fuel pump or a fuel injector in certain types of internal combustion engines. Especially in applications which require a pump with high reliability and small size, the pump according to the invention can be quite suitable. One example of such use is implantable pumps for insulin dosing, for example. Also fluid handling in analytical instruments for the chemical industry and medical applications can be done with a pump according to the invention.

Short description of the drawings

The invention will now be explained in more detail below and be exemplified with reference to a number of examples shown in the accompanying drawings.

Figs. 1a and 1b show the suction and pumping phases for a schematically shown embodiment of a pump according to the invention as seen in vertical section;

Figs. 2a and 2b show a cross-section through a conventional check-valve equipped membrane pump in its suction phase and pumping phase;

Figs. 3a and 3b show in longitudinal section a constricting element according to the invention with through-flow in the diffusor and nozzle directions, respectively;

Fig. 4 shows in diametrical cross-section a first embodiment of a pump according to the invention;

Fig. 5 shows in cross-section and in perspective another embodiment of the pump according to the invention;

Fig. 6 shows in cross-section a third embodiment of a pump according to the invention;

Fig. 7 shows, on a larger scale, the constricting element disposed on the inlet side (within the circle S) of the pump shown in Fig. 6; and

Fig. 8 shows, finally, schematically and in perspective a planar pump, the constricting element of which have rectangular cross-section.

Description of examples

Figs. 1a and 1b show schematically a cross-section through a displacement pump according to the invention in the form of a diaphraghm pump. The pump comprises a pump housing 2 with an inner pump chamber 4, the volume of which is variable and the defining walls of which comprise an elastically deformable wall portion 6 which, in the embodiment shown, is a flexible diaphragm. The diaphragm wall portion 6 moves alternatively out

(Fig. 1a) and in (Fig. 1b), thus varying the volume of the pump chamber and thus achieving the displacement effect of the pump. On the suction side of the pump, there is a fluid inlet 8 and on the pressure side of the pump, there is a corresponding fluid outlet 10. Both the fluid inlet 8 and the fluid outlet 10 comprise a constricting element 12 which is so designed and dimensioned that, for the same flow, there is a greater pressure drop in one flow-through direction (the nozzle direction) than in the opposite flow-through direction (the diffusor direction). The constricting elements 12 on the inlet (suction) and outlet (pressure) sides of the pump thus only differ to the extent that they are oppositely connected to the pump chamber 4. In Fig. 1a, the pump is shown during its suction phase when the diaphragm wall portion 6 is extended in the direction A, thus increasing the volume of the pump chamber 4. In Fig. 1b, the pump is shown during its pumping or displacement phase, when the wall portion 8 is moved inwards in the direction B, thus reducing the volume of the chamber 4. The inflow and outflow of the pump fluid at the inlet and outlet of the pump are illustrated with the solid arrows Φ_i and Φ_0 during the intake phase (Fig. 1a) and during the pumping phase (Fig. 1b). During the intake phase, the constricting element 12 at the inlet 8 provides a diffusor effect at the same time as the constricting element 12 at the outlet 10 provides a nozzle effect. During the pumping phase, the constricting element 12 at the inlet provides a nozzle effect, while the constricting element 12 at the outlet provides a diffusor effect. During a complete pumping cycle (intake phase + pumping phase), the pump thus produces a net flow from the inlet 8 to the outlet 10.

Figs. 2a and 2b show, for the sake of comparison, a conventional diaphragm pump 14 with passive flap-check valves 16, 18 at the inlet 8′ and outlet 10′. These check

valves are passively functioning flap valves which are moved between the open and closed positions solely by the movement and pressure of the pump fluid, if one neglects the force of gravity on the valve flaps. During the intake phase (Fig. 2a), when the volume of the chamber 4 increases, the valve 16 is open and the valve 18 is closed. During the pumping phase (Fig. 2b), when the volume of the chamber 4 is reduced, the check valve 16 is closed and the check valve 18 is open.

Figs. 3a and 3b show an example of a constricting element 12 according to the invention when there is flow therethrough in the diffusor direction (Fig. 3a) and the nozzle direction (Fig. 3b), respectively. The constricting element 12 is made as a rotationally symmetrical body 20 with a central flow-through passage 22. The flow-through passage 22 extends from an inlet area 24 to an outlet area 26. In Fig. 3a, the passage 22 is a diffusor area, while the passage 22 in Fig. 3b constitutes a nozzle area. In the latter case, the inlet area consists of the conical entrance 28 to the passage 22, and the outlet area consists of the other end area 30, i.e. the reversed situation to that shown in Fig. 3a.

Reference is now made to Fig. 4, which shows a diaphragm pump according to the invention. The pump housing 2 consists, in this case, of a circular disc or plate with a shallow, circular cavity 32 which forms the pump chamber 4 in the housing 2. At the bottom of the cavity 32, there is, firstly, an inlet aperture 34, and, secondly, an outlet aperture 36. The two constricting elements 12 thus constitute the fluid inlet 8 and the fluid outlet 10 of the pump. The pump chamber 4 is sealed at the top 40 of the housing 2 by means of the deformable wall portion 6 of the pump, which is a flexible diaphragm fixed to the pump housing 2. Directly above the pump chamber 4, a piezo-electric crystal disc 42 is fixed to

the outside of the diaphragm 6, and is the drive means to impart an oscillating movement to the diaphragm 6, thus causing the fluid volume enclosed in the pump chamber 4 to pulsate. The disc or drive means 42 is in this case a portion of a drive unit (not described in more detail here), which drives the wall portion 6 piezo-electrically. In principle, the wall portion or membrane 6 is brought into oscillation by applying an alternating electrical voltage over the piezo-electric crystal disc 42 glued, for example, to the diaphragm. The excitation frequency suitable for driving the pump by means of the piezo-electric disc 42 will be dependent on whether the pump fluid is a gas or a liquid. In a tested pump prototype, an excitation frequency on the order of 6 kHz proved suitable for pumping air, while a frequency of 200 Hz proved suitable for pumping water.

Fig. 5 shows a somewhat different embodiment of a displacement pump according to the invention. The basic difference between the embodiments shown in Figs. 4 and 5 lies in the placement and orientation of the constricting elements 12 forming the fluid inlet 8 and fluid outlet 10 of the pump. In the embodiment according to Fig. 5, the constricting elements 12 extend radially in diametrically opposite directions from the pump chamber 2. The central flow-through passages 22 of the elements 12 are in this case in connection with the pump chamber 4 via radial openings 44 and 46 at the inlet 8 and outlet 12 of the pump.

Finally, Fig. 6 shows an additional embodiment of a diaphragm pump according to the invention. The pump housing 2 is in this case in the form of a circular pressure box comprising an upper portion 48 and a lower portion 50 with flat end walls 52 and 54, respectively, and cylindrical and lateral walls 56 and 58, respectively. The lateral walls 56 and 58 are joined from opposite

sides to the peripheral edge portion of a diaphragm wall 60 of magnetic material, which, together with the end wall 54 and the lateral wall 58 define the pump chamber 4 within the lower portion 50 of the pump. Within the upper portion 48 of the pump, there is a chamber 62 which houses an electromagnetic drive unit 64, whereby the diaphragm wall 60 can be imparted the oscillating movement required to drive the pump. The two constricting elements 12 of the pump are in this case mounted in principle in the same manner as in the embodiment shown in Fig. 4.

Fig. 7 shows in a larger scale the fluid inlet 8 within the circle S in Fig. 6. The flow-through passage 22 of the constricting element 12 is in this case a slightly conical duct with a "point angle" $2\theta = 5,4°$.

Finally, it should be pointed out that there are two main types of diffusor geometries, namely conical and flat wall, which can be used for a pump according to the invention.

A conical diffusor has an increasing circular cross-section, while a flat diffusor has a rectangular cross-section with four flat walls, of which two are parallel. The two diffusor types have approximately the same diffusor capacity. The selection of the diffusor type for the pump according to the invention is therefore essentially dependent on the type of manufacturing process.

Fig. 8 shows a planar pump particularly suited for micro-working processes where the constricting elements 12 are integrated in a single structural piece which also constitutes the pump housing 2 surrounding the pump chamber 4 on four sides. The pump chamber 4 is also of course limited by an upper and a lower wall, but in Fig. 1 only

the upper wall 66 is shown for the sake of simplicity, and in this Figure it is shown lifted from the pump housing 2. One of these walls is the moveable/deformable wall portion of the pump.

Finally, it should be pointed out that the invention as defined in the following patent claims can, of course, be given many different embodiments differeing in various respects from the embodiments described above with reference to the drawings.

CLAIMS

1. Displacement pump with a pump housing (2) containing a pump chamber (4) of variable volume, the defining walls of said pump chamber comprising at least one moveable and/or deformable wall portion (6; 60), such as a flexible diaphragm, the movement and change in shape of said diaphragm causing variation in the volume of the pump chamber, thereby providing the displacement effect, said pump chamber (4) being provided with a fluid inlet (8) on the suction side on the pump and a fluid outlet (10) on its pressure side, c h a r a c t e r i z e d in that at least one of the fluid inlet (8) and the fluid outlet (10) comprises a constricting element (12), which, for the same flow has a greater pressure drop over the elements in one flow direction, the nozzle direction, than in its opposite other flow direction, the diffusor direction.

2. Pump according to Claim 1, c h a r a c t e r i z e d in that the constricting element (12) is arranged at the fluid inlet (8) or the fluid outlet (10) so that the diffusor direction of the element agrees with the flow direction for the pulsing flow from the fluid inlet (8) to the fluid outlet (10).

3. Pump according to Claim 1 or 2, c h a r a c t e r - i z e d in that the fluid inlet (8) and the fluid outlet (10) each comprise an individual constricting element (12) of the type described, the constricting element at the fluid inlet (8) being disposed so that its diffusor direction is directed into the pump chamber (4), while the constricting element (12) at the fluid outlet (10) is disposed so that its diffusor direction is directed out from the pump chamber (4), whereby the diffusor directions of both constricting elements agree with the

flow direction for the pulsing flow from the fluid inlet (8) to the fluid outlet (10).

4. Pump according to one of Claims 1-3, characterized in that the constricting elements (12) have a rounded shape at their inlet regions.

5. Pump according to one of Claims 1-4, characterized in that the elastically deformable wall portion (6; 60) of the pump chamber (4) consists of one or more flexible diaphragms, drive means (42) being associated to the respective diaphragm, whereby the diaphragm can be imparted an oscillating movement which causes the fluid volume enclosed in the pump chamber (4) to pulsate.

6. Pump according to Claim 6, characterized in that the drive means (42) is a portion of a drive unit (64), the frequency of the diaphragm oscillating movement imparted by the drive unit (64) being selected to provide a mechanical oscillating resonance which is dependent, on the one hand, on the mechanical resiliance of the oscillating diaphragm (60) and any resilient elements coupled to the diaphragm, and, on the other hand, on the mass of the pump fluid in respective constricting element (12) with associated ducts.

7. Pump according to one of the preceding Claims, characterized in that at least a portion of the pump housing (2) and associated constricting elements (12) constitute integral parts of a single structural piece.

8. Pump according to one of the preceding Claims, characterized in that it consists of at least one pump construction of silicon manufactured by means of a microworking process.

9. Pump according to one of the preceding Claims, c h a r a c t e r i z e d in that pressure equalizing buffer chambers, known per se, are coupled to the pressure and/or suction side of the pump and serve to reduce the pressure pulses of the pulsating flow.

AMENDED CLAIMS

[received by the International Bureau on 7 July 1994 (07.07.94); original claims 1-9 replaced by amended claims 1-8 (3 pages)]

1. Displacement pump with a pump housing (2) containing a pump chamber (4) of variable volume, the defining walls of said pump chamber comprising at least one moveable and/or deformable wall portion (6; 60), such as a flexible diaphragm, the movement and change in shape of said diaphragm causing variation in the volume of the pump chamber, thereby providing the displacement effect, said pump chamber (4) being provided with a fluid inlet (8) on the suction side on the pump and a fluid outlet (10) on its pressure side, c h a r a c t e r i z e d in that at least one of the fluid inlet (8) and the fluid outlet (10) comprises a constricting element (12), which constitutes a nozzle in its one through flow direction and constitutes a diffusor in its opposite other through flow direction, the pressure drop over such constricting element (12) being greater in its nozzle direction than in its diffusor direction for one and the same fluid flow, and that the constricting element (12) at the fluid inlet (8) and at the fluid outlet (10), respectively, being so directed that it constitutes a diffusor as seen in the direction of the net volume flow of the pump from the fluid inlet (8) to the fluid outlet (10) thereof.

2. Pump according to Claim 1, c h a r a c t e r i z e d in that the fluid inlet (8) as well as the fluid outlet (10) each comprise an individual constricting element (12) of the type described, the constricting element at the fluid inlet (8) constitutes a diffusor being disposed so that its diffusor direction is directed into the pump chamber (4), while the constricting element (12) at the fluid outlet (10) constitutes a diffusor being disposed so that its diffusor direction is directed outward from the pump chamber (4), whereby the diffusor directions of

both constricting elements agree with the flow direction for the net volume flow from the fluid inlet (8) to the fluid outlet (10).

3. Pump according to Claim 1 or 2, characterized in that the constricting elements (12) have a rounded shape at their inlet regions.

4. Pump according to one of Claims 1-3, characterized in that the elastically deformable wall portion (6; 60) of the pump chamber (4) consists of one or more flexible diaphragms, drive means (42) being associated to the respective diaphragm, whereby the diaphragm can be imparted an oscillating movement which causes the fluid volume enclosed in the pump chamber (4) to pulsate.

5. Pump according to Claim 4, characterized in that the drive means (42) is a portion of a drive unit (64), the frequency of the diaphragm oscillating movement imparted by the drive unit (64) being selected to provide a mechanical oscillating resonance which is dependent, on the one hand, on the mechanical resiliance of the oscillating diaphragm (60) and any resilient elements coupled to the diaphragm, and, on the other hand, on the mass of the pump fluid in respective constricting element (12) with associated ducts.

6. Pump according to one of the preceding Claims, characterized in that at least a portion of the pump housing (2) and associated constricting elements (12) constitute integral parts of a single structural piece.

7. Pump according to one of the preceding Claims, c h a r a c t e r i z e d in that it consists of at least one pump construction of silicon manufactured by means of a microworking process.

8. Pump according to one of the preceding Claims, c h a r a c t e r i z e d in that pressure equalizing buffer chambers, known per se, are coupled to the pressure and/or suction side of the pump and serve to reduce the pressure pulses of the pulsating flow.

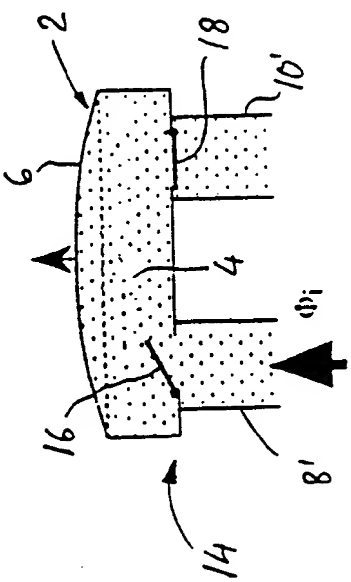


Fig. 2a
(Prior art)

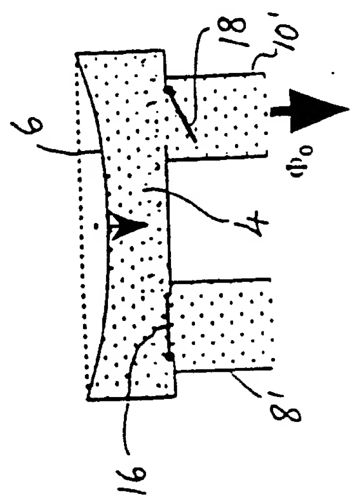


Fig. 2b
(Prior art)

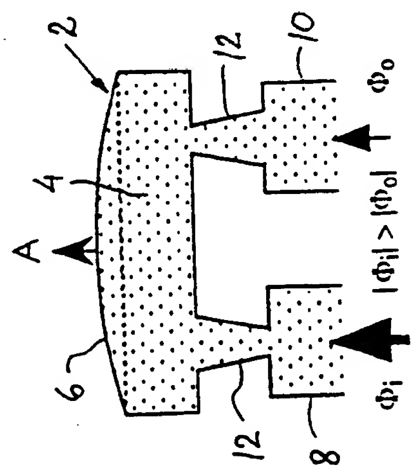


Fig. 1a

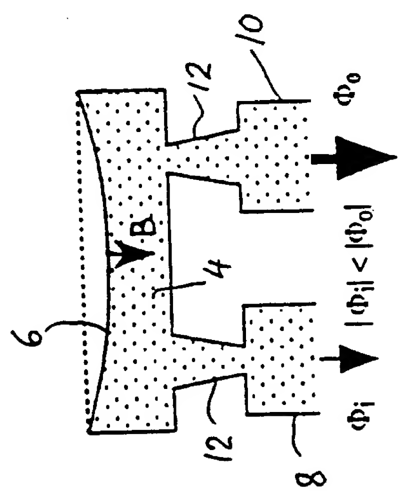


Fig. 1b

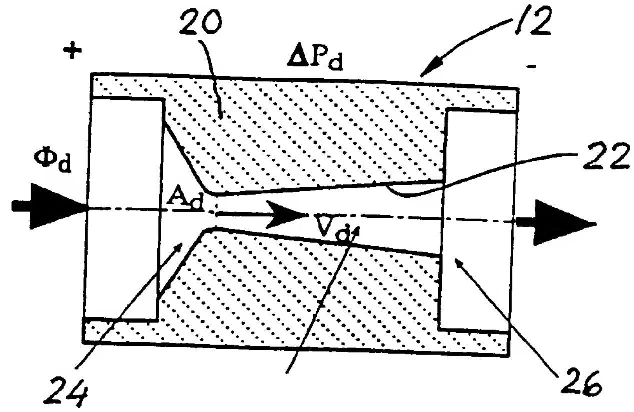


Fig. 3a

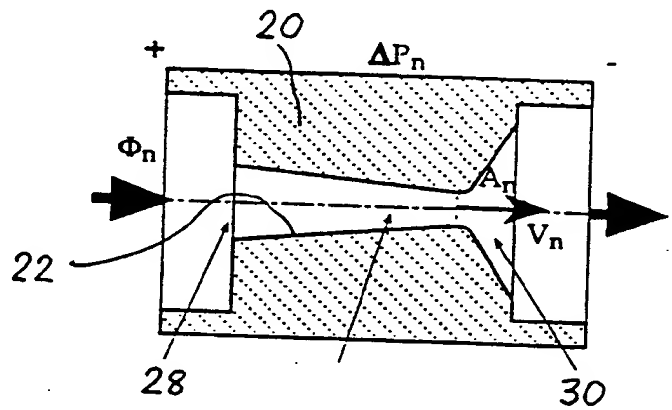


Fig. 3b

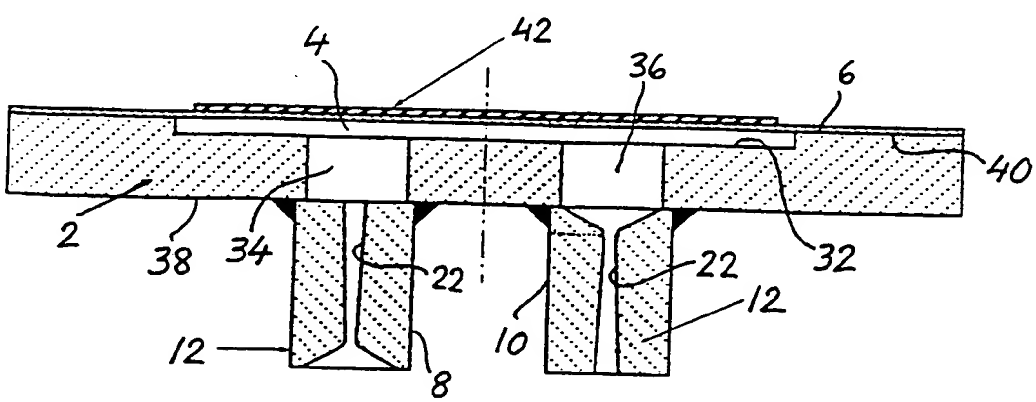


Fig. 4

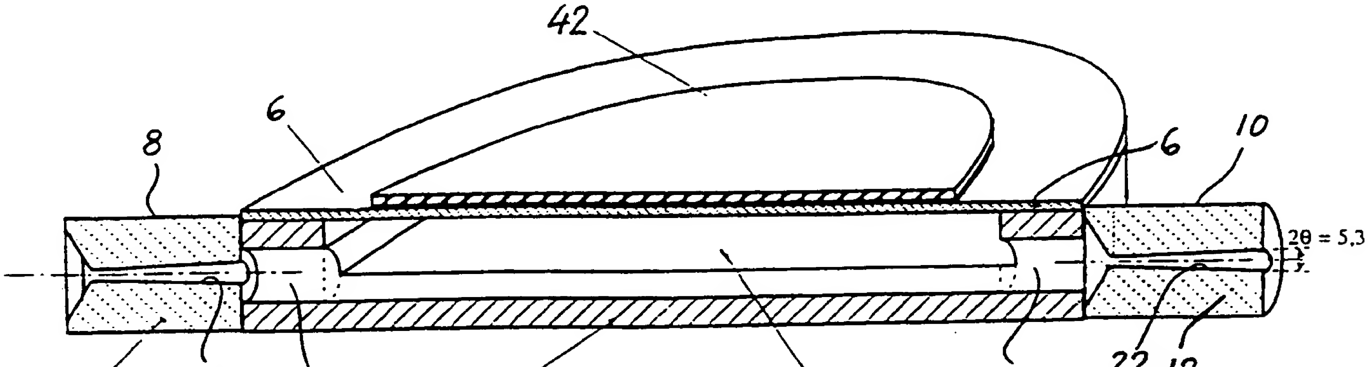


Fig. 5

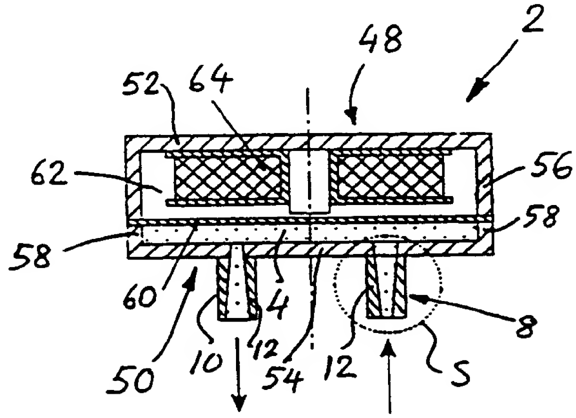


Fig. 6

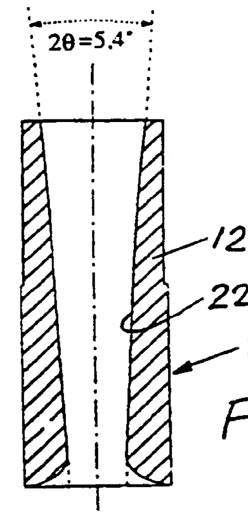


Fig. 7

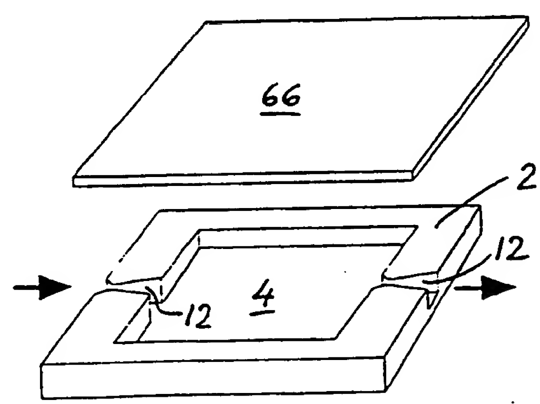


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/00142

A. CLASSIFICATION OF SUBJECT MATTER

IPC^5: F04B 43/02 // F04B 21/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC^5: B41J, F04B, F15D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Derwent's abstract, No F2482 E/18, week 8218, ABSTRACT OF SU, 846786 (KAUN POLY), 16 July 1981 (16.07.81) --	1-6
X	SE, B, 378029 (AB ORIGINAL-ODHNER), 11 August 1975 (11.08.75) --	1-4
X	DE, A1, 3442325 (SPRINGER, GEB. BRANDES, ET AL), 5 June 1985 (05.06.85) --	1-4
X	DE, A1, 2410072 (ROBERT BOSCH GMBH), 11 Sept 1975 (11.09.75) --	1-4

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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